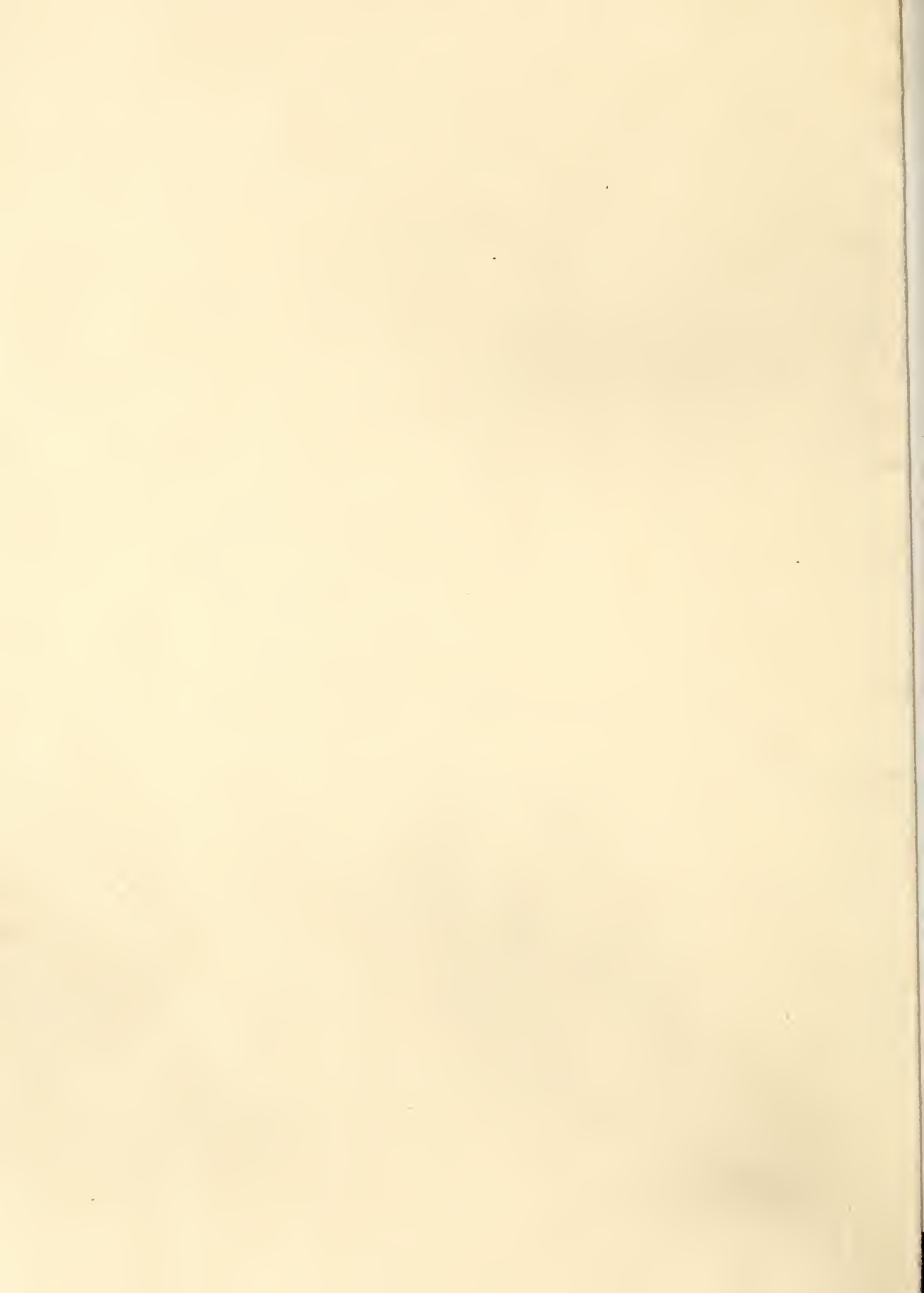


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CHEMICAL CHARACTERISTICS OF SOME FOREST AND GRASSLAND SOILS OF
NORTHEASTERN OREGON. I. RESULTS FROM REFERENCE PROFILE
SAMPLING ON THE STARKEY EXPERIMENTAL FOREST AND RANGE

by

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ABSTRACT

Chemical analyses of single profiles of six soil series on the Starkey Experimental Forest and Range were made to begin quantification of the soil resources in the Blue Mountains of northeastern Oregon.

Among the forest soils, available phosphorus was consistently much higher in the Tolo profiles while organic matter and total nitrogen values were found to be comparatively low. Couse and Klicker soils had higher levels of total exchangeable cations than did the Tolo soils.

Only minor differences were noted among grassland soils. However, the Rock Creek soil did appear to be quite low in available P, lowest of all the surface samples in both forest and grassland profiles.

INTRODUCTION

Published information on mountainous forest and associated grassland soils in eastern Oregon is primarily descriptive in nature, covering either general areas (Tarrant 1956, Anderson 1956) or specific

resource areas,¹ (Driscoll 1964, Strickler 1965). Information concerning the chemical characteristics of these soils is meager (Youngberg and Dyrness 1964) although some unpublished information exists.

The need for information on chemical characteristics of soils is not new but is rapidly increasing because of ever greater emphasis on optimizing productivity of forest and range lands. The multiple use program on National Forests often requires identification of productive potentials of landscapes for several products. Knowledge of soil chemical properties is essential for determining such potentials.

The overall objective of this study is the collection of soil chemical data which will characterize the fertility status of forest and grassland soils of northeastern Oregon and southeastern Washington. Seven individual profiles of six soil series were analyzed in this initial phase of the study. The seven profiles included several used as references in the soil survey of the Starkey Experimental Forest and Range² and other representative profiles on the Starkey.

In the Grande Ronde River drainage basin, various phases of the six series sampled occur on about 60 percent of a total of 3.17 million acres (Oregon State Water Resources Board 1969). Some classification characteristics of the sampled series are given in table 1.

STUDY AREA

The Starkey Experimental Forest and Range is located 30 miles southwest of La Grande, Oregon, on the main crest of the central Blue Mountains--an uplifted, faulted, and dissected formation of tertiary basalts. Elevations range between 3,800 and 5,000 feet. The climate is subhumid to semiarid with mean annual precipitation of 20 inches received as winter snows and spring and fall rains. The mean growing season on the soils studied ranges between 85 and 105 days, but frost can occur in any month.

Strickler (1965) described the associated vegetation on the Starkey. Forested soils commonly have an open to dense overstory of ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii* var. *glauca*) on the Klicker and Couse series and Douglas-fir, grand fir

¹E. W. Stevenson. Preliminary study of soils on the Starkey Experimental Forest and Range. Mimeographed, 12 p., 1950.

²Soil Survey, Starkey Experimental Forest and Range, Union and Umatilla Counties, Oregon. Soil Conserv. Serv. and Pac. Northwest Forest & Range Exp. Sta., USDA Forest Serv. Mimeographed, 32 p., 1960.

Table 1.--*Characteristics of six soil series on the Starkey Experimental Forest and Range*¹

Series	Subgroup	Family	Parent material	Example profile sequence	Depth
					<i>Centimeters</i>
Tolo	Typic Vitrandepts	Ashy over loamy, mixed frigid	Volcanic ash ² over basalt or buried soil	Al-AC-C-IIB21b-IIB22b-R	50-150
Klicker	Typic Argiudolls	Fine-loamy, mixed frigid	Basalt and loess	Al-A3-B1-B21t-B22t-R	40-75
Couse	Typic Haploxerolls	Fine-silty, mixed frigid	Loess and basaltic alluvium	Al-B21-B22-IIA2b-IIB21b-IIB22b-IIcB	90-170
Rock Creek	Lithic Argixerolls	Loamy skeletal, mixed mesic	Basalt and loess	Al-B2-R	5-40
Ukiah	Vertic Argixerolls	Fine, montmorillonitic, mesic	Mixed sedimentary	Al-A3-B1-B2-B3-C1-C2m	50-75
Albee	Typic Haploxerolls	Loamy, mixed frigid	Basalt and loess	Al-B1-B2-R	50-75

¹ Soil classification information (except Albee series) from: Placement of Series, West Region. USDA Soil Conserv. Serv., 229 p., 1968. Albee series classification: Arnold Ness, State Soil Correlator, Soil Conserv. Serv., Portland, Oreg., personal communication. Example profile sequence and depth data from: Soil Survey, Starkey Experimental Forest and Range, Union and Umatilla Counties, Oregon. Soil Conserv. Serv. and Pac. Northwest Forest & Range Exp. Sta., USDA Forest Serv. Mimeographed, 32 p., 1960.

² The Tolo series is currently being revised into two series, one having volcanic ash over basalt bedrock and the other having ash over a buried B horizon which was developed from basalt (Grant Lindsay, Soil Conserv. Serv., Baker, Oreg., personal communication).

(*Abies grandis*), western larch (*Larix occidentalis*), and lodgepole pine (*Pinus contorta*) on the Tolo series. The understory consists of various shrubs, forbs, and grasses dominated by pinegrass (*Calamagrostis rubescens*) and elk sedge (*Carex geyeri*). On grassland soils, Sandberg bluegrass (*Poa sandbergii*), onespoke danthonia (*Danthonia unispicata*), and, on the deeper profiles, scattered bluebunch wheatgrass (*Agropyron spicatum*) characterize the Rock Creek series. Idaho fescue (*Festuca idahoensis*) and bluebunch wheatgrass dominate the plant composition of Ukiah and Albee soils.

METHODS

Soil samples were collected in the following depth increments: 0-15 cm., 15-30 cm., 30-60 cm., 60-90 cm., and 90-120 cm. In some cases, rock prevented reaching the maximum depth. Samples were air dried after collection, passed through a 2-mm. sieve, and stored in plastic bags. Samples were analyzed for the following: total nitrogen by the Kjeldahl method (Jackson 1958, p. 187-190), organic matter by the Walkley-Black method (Jackson 1958, p. 219-221), extractable sodium and potassium by flame photometer, and extractable calcium and magnesium by versenate titration (U.S. Salinity Laboratory Staff 1954, p. 94-95). Extraction of all exchangeable cations followed the centrifugation method (U.S. Salinity Laboratory Staff 1954, p. 100-101). Available phosphorus was determined by sodium bicarbonate extraction (Olsen et al. 1954) modified according to the Murphy and Riley method discussed by Watanabe and Olsen (1965),³ and soil reaction in 0.01 M. CaCl_2 .

Values for the organic carbon to nitrogen ratios were computed by multiplying the organic matter values by 58 percent (assumed carbon content) and dividing by the total nitrogen content. Calcium to magnesium ratios were calculated from the exchangeable quantities of each. Sums of exchangeable cations were calculated for comparison. Cation exchange capacity determinations were also made but were not reported due to the inconsistent results obtained from various analytical methods. This inconsistency was most pronounced in the analyses of volcanic ash derived soils and those thought to contain more than minor amounts of volcanic ash. Data for total exchangeable cations represent a very gross comparison of cation exchange capacity and are discussed in this context.

³A wavelength of 810 nm. on a Coleman Junior II spectrophotometer was used in accordance with recommendations made by F. S. Watanabe, USDA, Agr. Res. Serv., Dep. Agron., Colo. State Univ., Fort Collins, Colo. (Mention of products by name does not constitute endorsement by the U.S. Dep. Agr.)

RESULTS

Chemical analyses are reported for forest soils (table 2) and grassland soils (table 3). Organic matter and total nitrogen of the upper profile and the exchangeable calcium, magnesium, and total exchangeable cations throughout the soil profile were consistently higher in the Couse and Klicker profiles than in the Tolo soils. Only available phosphorus had higher values in the Tolo soils and these values were very high. Relatively small differences were noted in pH, C/N ratios, or exchangeable sodium and potassium. Although most of the Ca/Mg ratios were in the 2/1 to 4/1 range, higher values were noted in the ash over basalt soil.

Organic matter, total nitrogen, C/N ratios, and available phosphorus decreased with increasing depth as one might expect. Abrupt changes in exchangeable calcium, magnesium, and total exchangeable cations are often related to profile features such as a clay-textured horizon or to some discontinuity such as the existence of a buried soil. Cases where the former exists are in the Couse and Klicker profiles at the 60-cm. depth. A case for the latter exists in the 90-120-cm. depth increment of the ash over buried soil.

Chemical properties of the grassland soils were similar to each other; however, in the Ukiah soil exchangeable calcium, magnesium, and total exchangeable cations show a strong increase with increasing clay content below the 30-cm. depth. This soil normally develops a dense clay horizon exhibiting prismatic structure at about 30-40 cm. Available phosphorus in the Rock Creek soil was quite low for surface soil material, lowest of all the soils studied.

Soil reaction values were about the same in both the forest and grassland soils. One will find that pH readings taken in 0.01 M. CaCl_2 will be from 0.5- to 0.8-pH units lower than readings taken in 1:1 or 1:2 distilled water dilutions (Black 1965, p. 919).

Calcium and magnesium appeared to be in a balanced ratio in all cases. The values at which one would expect problems related to an imbalance are not currently well defined; however, a ratio between 5/1 and 1/1 is considered most desirable (Black 1965, p. 1009).

The forest soils had higher C/N ratios than the grassland soils. This is to be expected with woodier types of organic materials as contrasted with the herbaceous materials of the grassland vegetation. Mineralization of organic nitrogen exceeds immobilization where narrow C/N ratios exist (20/1 to 30/1). The narrower the ratio, the more mineralization is favored (Alexander 1961, p. 265); hence, there should be a more rapid mineralization of nitrogen in the grassland soils in general.

Table 2.--Chemical characteristics of forest soil profiles

Soil series and depth increment (cm.)	Chemical properties										
	pH	Organic matter	Total nitrogen	Ratio C/N	Available P	Exchangeable cations				Ratio Ca/Mg	
						K	Na	Ca	Mg		Total
----- Percent ----- P.p.m. ----- Meq./100 g. -----											
Couse:											
0-15	5.5	6.52	0.21	18/1	12.6	0.7	0.2	21.1	7.8	29.8	2.7/1
15-30	5.5	6.61	.22	17/1	8.2	.4	.3	18.9	6.0	25.6	3.2/1
30-60	5.3	1.82	.08	13/1	4.8	.5	.4	17.0	7.8	25.7	2.2/1
60-90	5.4	.94	.04	14/1	2.6	.5	.7	25.5	12.5	39.2	2.0/1
90-120	6.6	.40	.02	12/1	2.4	.4	.9	29.5	14.5	45.3	2.0/1
Klicker:											
0-15	5.6	6.01	.18	19/1	22.1	1.5	.1	15.6	5.5	22.7	2.8/1
15-30	5.5	3.07	.11	16/1	21.0	.8	.1	13.7	5.5	20.1	2.5/1
30-60	5.6	1.47	.06	14/1	10.6	.8	.2	14.4	7.7	23.1	1.9/1
60-75	5.5	1.02	.04	15/1	11.7	.7	.2	17.3	9.6	27.8	1.8/1
Tolo ¹ (ash over basalt):											
0-15	5.4	2.70	.08	20/1	53.8	1.1	.1	5.2	1.1	7.5	4.7/1
15-30	5.6	1.29	.05	15/1	32.0	1.2	.1	5.8	.8	7.9	7.0/1
30-60	5.6	.83	.03	16/1	23.2	1.2	.1	6.0	.7	8.0	8.1/1
60-81	5.5	.79	.03	15/1	24.7	1.0	.2	5.6	.7	7.5	7.5/1
Tolo (ash over buried soil):											
0-15	5.8	2.12	.07	18/1	46.2	1.4	.0	6.5	1.9	9.8	3.5/1
15-30	5.6	1.07	.04	16/1	32.2	1.4	.1	5.3	1.5	8.3	3.7/1
30-60	5.4	.65	.03	13/1	29.0	1.3	.1	4.4	1.0	6.8	4.4/1
60-90	5.5	.60	.02	18/1	10.8	.8	.1	4.7	1.6	7.2	2.9/1
90-120 ²	5.5	.51	.03	10/1	11.3	.8	.2	9.4	4.5	14.9	2.1/1

¹Type location (benchmark profile) for this series.²The 90-cm. depth corresponds roughly to the upper boundary of a buried B horizon.

Table 3.--Chemical characteristics of grassland soil profiles

Soil series and depth increment (cm.)	Chemical properties										
	pH	Organic matter	Total nitrogen	Ratio C/N	Available P	Exchangeable cations				Ratio Ca/Mg	
						K	Na	Ca	Mg		Total
- - - - Percent - - - - P.p.m. - - - - Meq./100 g. - - - -											
Albee:											
0-15	5.7	3.37	0.16	12/1	16.0	0.9	0.1	10.6	3.0	3.6/1	
15-30	5.7	1.78	.10	10/1	6.8	.6	.1	10.0	3.2	3.2/1	
30-65	5.5	1.49	.09	10/1	10.0	.5	.1	9.7	3.4	2.9/1	
Rock Creek:											
0-13	5.3	3.75	.19	11/1	6.8	.6	.2	12.1	4.3	2.8/1	
Ukiah:											
0-15	5.6	4.02	.19	12/1	16.1	1.4	.1	10.9	2.8	3.9/1	
15-30	5.4	2.39	.13	11/1	8.5	.8	.1	10.6	3.6	2.9/1	
30-60	5.2	1.04	.08	8/1	6.2	.9	.3	16.5	7.7	2.1/1	
60-71	5.0	.56	.04	8/1	4.1	.8	.5	30.2	16.8	1.8/1	

Available phosphorus values of the grassland soils were similar to those of the Couse and Klicker forest soils. Perhaps the high levels of phosphorus in the ash soils are caused by phosphorus fixation by allophanic materials. No growth response to phosphorus additions would be expected on any of the soils with the exception of the Rock Creek profile. A response is generally unlikely above analysis values of 10 p.p.m. available P (Black 1965, p. 1046).

Exchangeable potassium values above 0.5 meq./100 g. are in the adequate to high range of available plant potassium. All of the soils appear to contain adequate potassium. Exchangeable sodium levels are low and do not present any toxicity problems. The dominance of calcium and magnesium on the exchange complex is common; no deficiencies of either of these elements would be expected.

Some unpublished data are available for comparison with three of the soils studied. Youngberg and Dyrness (1964) reported chemical analyses by horizon for a Tolo soil in central Oregon. They reported higher values for organic matter and total nitrogen content in the surface soil (9.17 percent and 0.19 percent, respectively). Exchangeable Ca and Mg values were generally higher in the central Oregon soil (ranges of 8.3-10.4 meq. Ca/100 g., 2.9-3.4 meq. Mg/100 g.); however, available P was lower (27-12 p.p.m.), and exchangeable K was about the same. Analyses made by Pettit⁴ on a Tolo soil in the Wallowa Mountain foothills of eastern Oregon showed very high available P (107-10 p.p.m.), similar levels of exchangeable K, but higher exchangeable Ca (9-13 meq./100 g.) and Mg (2-8 meq./100 g.). Other analyses of the Tolo soil over basalt on the Starkey Experimental Forest and Range made by Moore⁵ also showed higher Ca and Mg levels.

Comparison of the data from the Klicker soil analyses with those made by the Soil Conservation Service on two profiles sampled on the Starkey showed very similar results.⁶ One of the Klicker profile analyses reported in the Lincoln survey was apparently for the same profile sampled by the authors.

Hedrick et al. (1965, p. 41) reported some chemical analyses of a Couse profile in the foothills of the Wallowa Mountains. Their results were essentially the same for pH (allowing for methodology differences);

⁴ R. D. Pettit. Effects of seeding and grazing on a clearcut burn in a mixed-coniferous forest stand of the Wallowa Mountain foothills. Diss., Ore. State Univ., 133 p., 1966.

⁵ Duane Moore, Forest. Sci. Lab., Forest Serv., Corvallis, Ore., personal communication.

⁶ Lincoln Soil Survey Laboratory Report for Soils Sampled in Union County, Oregon. Lab. Staff, Soil Surv. Lab., Soil Conserv. Serv., USDA., Lincoln, Nebr. Unpublished report, 48 p.

organic matter values were somewhat lower in the upper 30 cm. (4.23 percent, 0-15 cm.; 2.23 percent, 15-30 cm.) but similar below 30 cm. The surface soil nitrogen content was reported as 0.19 percent which was essentially the same. Available phosphorus was higher throughout the profile, ranging from 27 p.p.m. in the upper 15 cm. to 4 p.p.m. at 100 cm.

The importance of the differences between results cited in the literature and the results reported herein may not be readily apparent. Certainly the differences due to sampling technique (horizon vs. fixed depth) have an effect on magnitudes of the numbers reported; however, these should be reconciled with weighted averages if the soils are similar in all respects. Instead, the differences are probably due to the combined effects of differing soil forming factors (climate, vegetation, etc.). One will find that considerable variability is allowed in many soil series in both chemical and physical characteristics. Hence, a single profile analysis cannot be considered wholly representative of its parent series, and the reader is cautioned in the use of these results. Youngberg and Dyrness (1964) noted sizable differences among soil nitrogen values in a Lapine series under different plant communities. Indeed, it would not be unusual to find greater differences between analytical values within a single soil series than among different series. Future analytical results should reveal the ranges in chemical characteristics to be expected within each series as related to vegetational, geographic, and other gradients.

SUMMARY

Chemical analyses of single profiles of six soil series on the Starkey Experimental Forest and Range were made to begin quantification of the soil resources in northeastern Oregon. Although these results are considered to be fragmentary in relation to all occurrences of these series, several notable differences were found.

Among the forest soils, available phosphorus was consistently much higher in the Tolo profiles while organic matter and total nitrogen values were found to be comparatively low. Couse and Klicker soils had higher levels of total exchangeable cations than did the Tolo soils.

Only minor differences were noted among grassland soils. However, the Rock Creek soil did appear to be quite low in available P, lowest of all the surface samples in both forest and grassland soils.

Many analyses yielded similar results among all soils studied. Exchangeable K, Na, Ca, and Mg showed similar trends with increasing soil depth, as did organic matter and total nitrogen. Calcium to magnesium ratios and pH values were similar for all soils; however, forest soils exhibited consistently higher C/N ratios than grassland soils at all soil depths. Future analyses of soils sampled at other locations will lend insight into the variability of these chemical properties within these and other soil series.

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